

# Relationship between Length of Gestation, Birth Weight and Certain Other Factors\*

## A Statistical Study

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*It is well known that there is a relationship between the weight of the foetus and the length of gestation, but both these elements may be affected by a variety of factors which may be of importance to the viability and developmental potential of premature infants and of those born at term. A number of these factors are considered in this study, which is based on data in the literature and on relatively extensive case material from Poland.*

*Statistical analysis suggests that there is slight correlation between the weight of the foetus on the one hand and, on the other, the weight of the placenta, the height of the mother and the age of the mother.*

*The author concludes, inter alia, that the relation between foetal weight and length of gestation, being easily determined, is of value in routine clinical practice as a general guide to the degree of maturity of an infant, but that other more precise measures need to be developed.*

In discussing the relationship between the length of gestation and the birth weight the fact must be borne in mind that both elements of this relation are conditioned in many different ways and that they show a wide variability.

This problem is a very old one (Zangenmeister, 1911; Streeter, 1920; Wehefritz, 1927; Hosemann, 1949; Wylie & Amidon, 1951; Thomson, 1951). It has been frequently raised because it is of great importance for routine paediatric, obstetrical and forensic practice. Furthermore, it has many theoretical aspects which, if recognized, may be helpful in the solution of various problems of reproduction and many current needs of maternal and child care as well. Therefore maternal and child care should be discussed as a factor of primary importance in considering the practical possibility of influencing the length of gestation and the birth weight by improvement in the conditions of development of the foetus and child.

The first question which arises in connexion with this problem is that of more precise definition of the "normal" length of gestation and "adequate" birth weight, which assure normal development of the child and its capacity for normal reproduction in the future. A uniform answer to this apparently simple question is, in reality, rather difficult to give.

The generally prevailing opinion is that the length of gestation and the birth weight are closely correlated. This is supported by the results of research both recent and old, and by statistical studies, as shown in Table 1, which gives the average weight by lunar months quoted in standard texts.

The curves of Hosemann (1952), Crosse (1952), and Huggett (1946-47) and my own (Fig. 1)—which is based on 1958 data from the Institute of Mother and Child Health in Warsaw—as well as the correlation coefficient shown in Table 2 demonstrate a similar close correlation between the length of gestation and the birth weight.

The same correlation also exists for prematurely born infants (correlation coefficient:  $r=0.61$  for 865 cases from the above-mentioned Institute in the years 1953-59).

Unfortunately the limits for length of gestation are too wide. On the average, in our material, normal

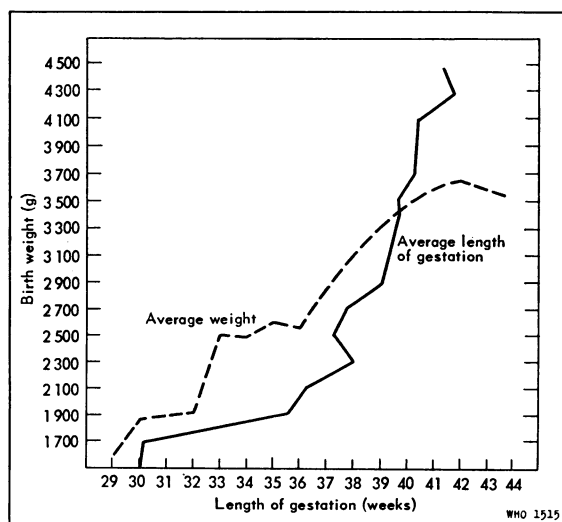
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TABLE 1  
WEIGHT OF FOETUS (IN g) THROUGHOUT GESTATION ACCORDING TO DIFFERENT AUTHORS

Reference	Lunar months									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Bodiazyna (1949-55)	—	—	20 25	120	280 300	600 680	1 000 1 200	1 500 1 600	2 400 2 500	3 200 3 400
Gesell (1945)	—	—	—	—	—	700	1 200	1 500	2 100 2 400	3 000
Kaplan (1941)	—	—	20	120	300	600 700	1 000 1 200	1 500	2 500	3 200 3 400
Mikulicz-Radetzky (1954)	—	—	35	100	300	600 700	900 1 200	1 500 1 700	2 000 2 500	3 000
Kerr et al. (1944)	—	4	30	130	250	680	1 100	1 570	2 650	3 200
Streeter (1920) Williams (1956) Speert & Gutmacher (1956)	—	1	14	108	316	630	1 045	1 680	2 478	3 405
Scammon & Calkins (1924-25)	—	3.5	14	86	260	551	971	1 519	2 196	2 998
Pigeaud (1953) Weibel (1941)	—	2 3	10 12	87	280	700	1 300	2 220	3 250	—
Žordanija (1959)	—	—	20	120	280 300	600 700	1 000	1 500 1 600	2 500	3 200 3 500
Zangenmeister (1911)	1	2.8	12	89	252	795	1 066	1 540	2 243	3 242

FIG. 1  
CORRELATION BETWEEN BIRTH WEIGHT AND LENGTH  
OF GESTATION <sup>a</sup>



<sup>a</sup> Based on data from the Institute of Mother and Child Health, Warsaw.

gestations ended after 278-283 days, or 39.5-40 weeks. This period varies, however, in the literature from 266 days to 320 days and longer (McKeown & Gibson, 1952; Hosemann, 1952).

In estimating the length of gestation we have to rely on certain empirical and conventional data, as we do not know definitely when impregnation or nidation occurs.

Similarly, birth weight is also an unstable element. The birth weight of full-term infants in different countries and in different areas within individual countries shows wide variations. For example, an average birth weight of 2823 g has been reported for the French Sudan, 3242 g for France and 3400 g for North America (Canivet, 1949; Meredith, 1948). In Poland the average birth weight varied in the years 1952-57 as follows, according to data from the Ministry of Health: <sup>1</sup>

1952 . . . . .	3366 g
1953 . . . . .	3363 g
1955 . . . . .	3371 g
1956 . . . . .	3366 g
1957 . . . . .	3358 g

<sup>1</sup> Data are not available for 1954.

TABLE 2  
CORRELATION BETWEEN WEIGHT OF FOETUS AND LENGTH OF GESTATION, AS SHOWN BY NUMBERS  
OF BIRTHS OBSERVED AT THE INSTITUTE OF MOTHER AND CHILD HEALTH, WARSAW

Week of pregnancy	Weight (g)																Total
	1 401- 1 600	1 601- 1 800	1 801- 2 000	2 001- 2 200	2 201- 2 400	2 401- 2 600	2 601- 2 800	2 801- 3 000	3 001- 3 200	3 201- 3 400	3 401- 3 600	3 601- 3 800	3 801- 4 000	4 001- 4 200	4 201- 4 400	4 401- 4 600	
29	4	3															7
30	1	2				1											4
31																	
32	2	1		1			1										5
33					1		1										2
34						1											1
35			1			1	1			1							4
36			1	4	1	4	2		2	2							16
37					2	2	13	5	4	2			1				29
38				1		4	12	20	17	18	8	4	1	3			88
39				1	1	4	6	19	33	35	37	23	12	2		1	174
40					2	1	6	15	32	52	50	34	27	15	2	1	237
41						1		6	15	15	26	24	22	12	5	2	128
42					1				2	7	4	10	6	6	3		39
43								1	1	4	1	6	2		4	3	22
44								1				1			1		3
Total	7	6	2	7	8	19	42	67	106	136	126	102	71	38	15	7	759

Average weight of foetus=3344 g.

Standard deviation of weight of foetus=510 g.

Average length of gestation=39.5 weeks.

Standard deviation of length of gestation=2.0 weeks.

Correlation coefficient:  $r=0.67$ .

In view of the foregoing it appears desirable to consider the various factors influencing the length of gestation and the birth weight, and to determine what is the correlation between them and what is their relative importance to the viability and developmental chances of premature infants.

#### FACTORS INFLUENCING THE LENGTH OF GESTATION

Table 3, giving the length of gestation among different species of animals, shows that there is a positive correlation between the average duration of life, weight and the length of gestation.

There are, however, individual differences in the length of gestation among various breeds of animals of the species (Keller, 1924).

Among humans the average length of gestation varies between 39.5 and 40 weeks. There are some

differences in this respect among various races and nations (e.g., Slavs, the Nordic peoples, Chinese, Japanese).

The menstrual cycle is also considered to be a factor greatly affecting the length of gestation. In spite of individual differences in the length of the menstrual cycle it has been found that there is a definite correlation between the length of gestation and the length of the menstrual cycle (Knaus, 1955; Lanser & Wahl, 1940; Szenker, 1926-27).

Factors such as the age of the woman, the constitution of the parents, the type of employment, nutrition and parity seem not to affect the length of gestation in any very obvious way.

The extent to which the foetus itself may influence the length of gestation is a very interesting problem.

From the biological point of view it may be said that gestation is a period of maturation or, as some

TABLE 3  
LENGTH OF GESTATION FOR VARIOUS ANIMAL  
SPECIES

Animal	Length of gestation (weeks)	Average weight of adult animals (kg)	Average duration of life (years) <sup>a</sup>
Mouse, hamster, rat, rabbit	3	0.05-4	2-6
Squirrel	4	0.5	8-10
Guinea-pig, fox, cat	9	0.5-7	6-8
Pig	16	80-150	20-25
Sheep	21	20-30	10-15
Deer	33	60-100	20
Monkey	38	50-70	30
Cow	41	200-300	30-35
Horse	48	300-400	30
Donkey	52	150-300	30-35
Rhinoceros	76	2 000-3 000	40-50
Elephant	90	4 000	70

<sup>a</sup> From Brehm (1956).

say, of incubation of the foetus, and that gestation ends by labour when the foetus is ready for extra-uterine and self-supporting life.

As has been said, there is for every species a specific and stable length of gestation under definite conditions of maternal environment, among which is included the adaptation of the foetus to independent life. In nature, however, there are seemingly astonishing contradictions or exceptions to that general principle. For example, the length of gestation in the beaver and doe is longer at certain seasons of the year (Hosemann, 1952).

In the light of the foregoing, one is driven to the conclusion that the length of gestation is determined by some factor or factors which may be of hereditary origin. This factor may be the egg cell itself, or one of hereditarily conditioned developmental dynamics, sometimes individually different but specifically common.

According to some observers (Hughes, 1955; Hosemann, 1952; Leitch, 1957; Thomson, 1951) the dynamics of gestation are at their peak in the embryonic period and fall off slowly with the approaching birth. This is confirmed by investigations of the

metabolism of the placenta (Flexner et al., 1948) and of the uterus (Assali et al., 1960).

The process of regressive alterations in the placenta—sometimes called aging of the placenta—suggests the possibility that the length of gestation may be determined by the foetus itself, its growth and the character of its metabolism. This view coincides with that of Huggett (1946-47), who considers that the growth of the foetus decreases proportionally with the intensity of its metabolic processes.

At the beginning of gestation the particular maternal-foetal metabolism assigns the role of a parasite to the foetus. This parasitic condition gradually disappears with the growth of the foetus and with its increasing self-reliance.

In other words, on the basis of recent physiological research, we may return to the old concept of Hippocrates that the foetus is born when it feels hunger, or that the decrease in the foetal metabolic rate determines the moment of its birth.

We have tried, *inter alia*, to establish the relation between the weight of the placenta and the birth weight, but the correlation coefficient was low ( $r=0.23$  for 732 cases).

Some authors (Hosemann, 1952; Dunham, 1957) consider that the development of the foetus is not a continuous phenomenon but occurs in phases of increased and decreased growth. The existence of such phases of decreased development of the foetus might explain several seemingly inexplicable observations; for instance, the birth of slowly growing foetuses in which all signs of maturity are delayed in relation to the average period of gestation, or the "immaturity" of post-term babies. This view might also partly explain the odd course of gestation in the beaver and doe.

Hosemann (1952) suggests that the length of pregnancy is a function of time rather than of maturity.

#### FACTORS INFLUENCING THE WEIGHT OF THE FOETUS

Genetic factors are among the most important of those affecting foetal weight. The sex, as is well known, is strictly genetically determined. It is also generally known that the weight of the female infant, is, on the average, lower than that of the male.

There are some data available concerning the heredity of the weight potential of the foetus based on experiments performed on animals (Fahlbusch, 1934).

Similar observations have been made in man by Morton (1955) in Hiroshima and Nagasaki. He

found that children of the same mother but of different fathers were more closely alike in regard to weight than children of the same father but of different mothers. These observations might indicate the secondary importance of the father in determining the weight potential of the foetus. This statement is supported by Garry & Stiven (1935-36), who consider that the weight of the child depends primarily on the growth impulse of the foetus and the constitution of the mother.

The race factor may also play some role in determining the birth weight, as has been shown by Canivet (1949), Meredith (1948) and Taback (1951). They observed marked variations in birth weight among the newborn in Okinawa, South Africa, France and North America.

The possible influence of certain special genetic characteristics of the mother on the course of reproduction and on the weight of the foetus has also been shown by the investigations carried out by Žordanija (1959), who was able to demonstrate that the degree of ramification of the placental vessels which influences the haemodynamics of the foetus is a hereditary trait.

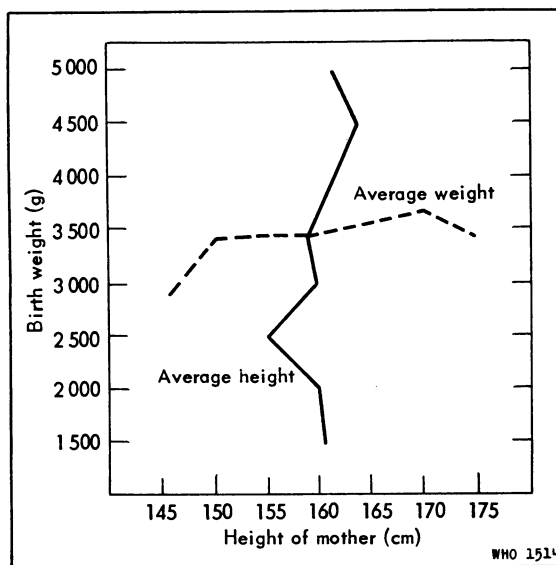
The reproductive conditions also vary with age and parity of women, and similar factors influence the weight of the foetus. It has been observed in India that among very young couples their first children have a lower weight than their later ones (Huggett, 1946-47). Similar data have been collected in experiments on animals (Walton & Hammond, 1938).

In our material we examined only the relation between the age of the mothers and the weight of the foetus. The correlation was low ( $r=0.15$  for 732 cases).

The influence of the height of the mother upon the weight of the foetus is still an undecided question. The studies of Walton & Hammond (1938) on Shetland-Shire hybrid horses, showing that the birth weight of the foals was related to the height of their dams, as well as the observations of Baird (1945) that the weight of the human foetus varies in each month of gestation with the height of its mother, could not be fully confirmed in our material of a few hundred newborn infants. The correlation between the weight of the foetus and the height of the mother, though statistically significant, was very low ( $r=0.17$  for 732 cases) (Fig. 2).

Leitch (1957) assumes, with some justification, that the weight of the foetus is influenced to a greater extent by the environment the mother creates during

FIG. 2  
CORRELATION BETWEEN BIRTH WEIGHT AND HEIGHT OF MOTHER<sup>a</sup>



<sup>a</sup> Based on data from the Institute of Mother and Child Health, Warsaw.

its intra-uterine development than by genetic characteristics of the foetus.

Obstetricians are now more prone to believe that efficient function of the maternal genital organs is a prerequisite for the normal development of the foetus and for the development of its normal birth weight and adequate length of gestation. Therefore more importance has been attached lately to investigations of the preconceptional conditions of reproduction (Turpin, 1955; Hughes, 1955).

Environmental factors without any doubt affect the weight of the foetus.

Obviously the closest environment of the developing foetus is its mother and her uterus and appendages—placenta, membranes etc. Their functional efficiency conditioned preconceptionally may play an important role in their later development and in the formation of some definite characteristics, including, among others, the weight of the foetus. The functional state of the uterine mucosa in the course of gestation (decidua), the circulation of the uterus and the relation of that circulation to the foetal circulation in the placenta, the gaseous metabolism as well as the metabolism of the basic nutritional agents, and various chemical reactions

(hormones, enzymes, electrolytes etc.) very often determine the direction and the rate of foetal development.

The nutrition of the pregnant woman is without any doubt an important factor in foetal development (Huggett, 1946-47; Botello Llusia, 1951; Thomson, 1951; Hughes, 1955; Leitch, 1957). Insufficient and inadequate nutrition may result not only in some serious disorders in the developing foetus but even in its death. Of main importance are certain serious deficiencies in various nutritional elements. Prolonged nutritional deficiency of the mother, especially in the second half of gestation, affects to some extent the weight of the foetus. This has been proved by numerous observations on the weights of children born in times of war and famine (Antonov, 1947; Huggett, 1946-47).

It seems that extensive nutritional deficiencies preceding impregnation and persisting during gestation might affect the weight of the foetus considerably and to a greater extent than deficiencies appearing in the course of gestation only.

In discussing the influence of the nutrition of the pregnant woman upon the foetus we have to consider some mechanisms of that influence on its weight. These mechanisms may have different forms.

As mentioned above, a quantitative nutritional decrease is not reflected clearly in the development of the foetus. Much more important may be some indirect mechanisms. One of these is metabolic insufficiency in a pregnant woman. She herself may not be consuming a proportionate amount of recommended food, or, having ingested it, may fail to digest, absorb or utilize the food. In such cases, in spite of nutritional amounts sufficient to meet the energy requirements of the pregnant woman, deleterious consequences for the foetus may ensue.

As still another mechanism of trophic disorders of the foetus one must consider the deficiencies caused by pathological conditions in the organism of the mother; e.g., pathological changes of the uterine mucosa, abnormal development of the decidua and, very often connected with it, the abnormal situation of the placenta, as well as kidney and urinary diseases, circulatory disorders associated with stasis at the periphery of the placenta and in the lining of the uterus, pathological changes in the vessels frequently occurring in the course of diabetes, hypertension, pre-eclampsia and various infections.

Anaemias in pregnancy unfavourably affect the development of the child (Knörr, 1957; Huggett, 1946-47). They do not, however, to any great extent affect the weight of the foetus at birth but are of importance for its later development (Huggett, 1945).

In our study on the relationship between the length of gestation and the weight of the foetus we have found, as mentioned already, the quite high correlation coefficient of  $r=0.67$  (Table 2).

A control study of the relation between the length of the foetus and the length of gestation gave us a similar degree of correlation (Table 4).

#### DISCUSSION

On the basis of our limited investigations and from data in the literature concerning the weight of the foetus and the length of gestation, we may state that the weight of the foetus cannot be considered the only criterion in estimating its degree of maturity. Such an estimation must be based on some additional criteria and requires highly trained paediatric and obstetrical personnel. It is necessary, therefore, to continue research on the developmental processes of the foetus on the basis of more precise and adequate criteria, especially concerning the estimation of its degree of maturity and its biological potential.

Some extensive research is indeed being carried out along the above lines; there are, for instance, the investigations of the haemoglobin level by de la Fuente & Vila (1958), the estimation of the ossification centres in the bones of the lower extremity of the foetus (Harnack & Oster, 1958), and investigations by means of the Gesell test, which, according to Bergström & Söderling (1958), permits differentiation between prematurity and pseudomaturity. Finally, some efforts have been made to define the limits of maturity or deficiency of birth weight of the foetus by means of an index derived from the length: weight ratio (see the studies of Bielecka & Winnicka (1962) in Poland).

There are certainly other possibilities also for further investigations, among which should be most seriously considered research on the pre- and post-conceptual conditions of foetal development and on the genetic factors determining that development. Such investigations might make a very practical contribution to facilitating estimation of the degree of maturity and of the biological qualities of the foetus.

TABLE 4

CORRELATION BETWEEN THE LENGTH OF GESTATION AND THE LENGTH OF THE FOETUS, AS SHOWN BY NUMBERS OF BIRTHS OBSERVED AT THE INSTITUTE OF MOTHER AND CHILD HEALTH, WARSAW

Length of foetus (cm)	Length of gestation (weeks)																Total
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
40		1		2													3
41		1					1										2
42	2							1			1						4
43		1		1				1									3
44								2		2		1					5
45					1			2	2		2	1					8
46		1		1		1	1	3	2	4	1	1					15
47				1	1		1	1	10	5	11	9	3	2	2		46
48									4	16	13	14	3	1	1		52
49								3	3	27	29	29	17	3		1	112
50								2	7	14	46	64	22	2	2		159
51							1		1	9	32	56	27	3	3		132
52										4	18	29	19	15	2		87
53										2	12	25	24	6	7		76
54												5	6	4	2	1	18
55												2	3	3	1	1	10
Total	2	4	0	5	2	1	4	15	29	83	165	236	124	39	20	3	732

Average length of foetus=50.1 cm.

Standard deviation of length of foetus=2.3 cm.

Average length of gestation=39.5 weeks.

Standard deviation of length of gestation=1.9 weeks.

Correlation coefficient:  $r=0.61$ .

#### CONCLUSIONS

From our investigations and the above considerations we may draw the following conclusions.

1. There is a considerable relationship between the weight of the foetus and the length of gestation; but

(a) the weight of the placenta is slightly correlated to the weight of the foetus;

(b) the correlation between the height of the mother and the weight of the foetus is slight; and

(c) there is only a slight correlation between the age of the mother and the weight of the foetus.

2. In clinical routine, the weight in its relation to the length of gestation is important mainly for a general estimation of the maturity or degree of underweight of the foetus because it is easily measured; other, more precise, methods of determination of the

maturity and biological viability of the foetus have yet to be developed.

3. On the whole one can say that at about the 28th week of gestational life the foetus reaches the stage of development, weight and biological viability at which extra-uterine life should be possible. In some regions of the world (e.g., South Africa, Japan, China, and elsewhere, the limit of prematurity should be established at 2250 g or 2350 g, as has been suggested by Taback (1951), according to the biological rhythm of intra-uterine development peculiar to the peoples of those regions.

4. The intrinsic environment in which the foetus develops during gestation—the physiology of reproduction in its widest sense and especially the physiology of the foetus itself as well as of the uterine mucosa (decidua) and its relationship to the placenta—must be considered a field for further scientific research.

## RÉSUMÉ

Il est admis qu'il existe un rapport entre le poids ou la longueur du fœtus et la durée de la grossesse, mais chacun des termes de cette relation est sujet à variations sous l'influence de divers facteurs. Après avoir passé en revue la littérature consacrée à l'action éventuelle de ces facteurs (hérédité, race, environnement, régime alimentaire, métabolismes de la mère ou du fœtus, particularités anatomophysiologiques des organes de la conception, etc.), l'auteur rappelle que l'analyse statistique fait apparaître un faible degré de relation entre la plupart d'entre eux et le développement du fœtus.

En revanche, ses propres statistiques d'une relation entre le poids et la longueur du fœtus d'une part et la durée de la grossesse, d'autre part (respectivement 759 et 732 cas suivis en Pologne), confirment l'existence d'une relation certaine et marquée. Par ailleurs, il existe peu de relation entre le poids du fœtus et le poids du placenta, la taille ou l'âge de la mère.

Dans la pratique, la relation du poids à la durée de la grossesse est un moyen commode de se faire une opinion sur le degré de maturité ou d'insuffisance pondérale de l'enfant. Cependant, il reste à découvrir des méthodes plus précises d'évaluer la maturité et la viabilité biologique. Des recherches sont en cours: étude du taux de l'hémoglobine, des points d'ossification du membre inférieur et application du test de Gesell — qui permettraient de différencier la prématurité de la pseudo-maturité.

D'une manière générale, on admet que le fœtus atteint à la 28<sup>e</sup> semaine de vie intra-utérine un stade de développement pondéral et biologique qui lui permet une vie indépendante.

La recherche devra s'attacher à étudier l'environnement immédiat du fœtus au cours de la gestation, et notamment la physiologie même du fœtus, celle de la muqueuse endo-utérine et des relations fœto-placentaires.

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